

SMALL GROUND ROBOT'S EFFECTIVENESS AND ACQUISITION STRATEGY

BY

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SMALL GROUND ROBOT'S EFFECTIVENESS AND ACQUISITION STRATEGY

by

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ABSTRACT

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Small Ground Robots Effectiveness and Acquisition Strategy is a review of current unmanned ground vehicle technologies within the Future Combat System /Army Brigade Combat Team Modernization Program, a One Semi-automated Force based analysis of these system's impact on the effectiveness and efficiency of infantry units and a recommendation of acquisitions strategies as these technologies enter the force through programs of record. The report finds that there are significant increases in small infantry unit combat effectiveness as objectively measured by lethality, survivability, and mission accomplishment. Additionally, small unit leaders gain previously unavailable situational awareness opening tactical options previously unavailable in the current fight under our current restrictive rules of engagement. Further, an analysis of potential acquisition strategies recommends movement away from the current theater provided equipment model of the systems and instead pushes for the adoption of the technology as MTOE equipment focusing on leveraging scheduled software and processor upgrades to maintain equipment as state of the art.

SMALL GROUND ROBOT'S EFFECTIVENESS AND ACQUISITION STRATEGY

Since the beginning of combat operations in Afghanistan, the United States has capitalized on its technological base and innovation to develop sophisticated robotic systems to assist commanders in performing surveillance, reconnaissance, target identification and tunnel exploitation. As operations expanded in Iraq, commanders needed new tools to defeat an evolving enemy's emerging tactics and weapons – the development of Improvised Explosive Devices (IEDs). These conditions have led to the expansion of robotic capabilities in the air and ground domains. Though the robotic systems' prominence among the public has happened over the last seven years, the United States, our allies and our enemies have been using tele-operated machines for war since World War I.

As impressive and enduring as the current systems are, there are still significant areas where the robotic systems have yet to achieve their full capabilities. Army and Marine leaders are now examining the integration of small ground robots into infantry formations and the impact that integration will not only have on unit effectiveness, but also on the institution in the areas of Doctrine, Organization, Training, Material, Leadership and Education, Personnel, Facilities and Policy (DOTMLPF-P). The Army's efforts have been focused on the now defunct Future Combat System's "System of Systems" and the current Brigade Combat Team Modernization Increment 1 technologies. Though both of these efforts include small ground robots, they focus on the system's ability to be used in extensively networked environments. Though the ability to

interface with command and control systems throughout the formation brings tremendous value to the warfighter, without the network, these same robots can give small unit infantry leaders a tremendous advantage over enemy formations in urban terrain found in Iraq and Afghanistan. The robot integrated infantry units not only gain advantage over the enemy, they are more effective and efficient when compared to identically structured infantry units that do not have robots.

As part of the Total Army Analysis, the Army has committed to deploying the matured Increment 1 technologies as Capability Packages to the 29 Infantry Brigade Combat Teams (IBCTs) between 2014-2016.¹ Though these acquisitions are currently being programmed, it is not yet clear which capabilities will survive to final acquisition, and the most effective means of fielding these technology based capabilities.

Background

All of the robotic systems employed by the United States in Operation Enduring Freedom and Operation Iraqi Freedom are tele-operated. This means that the Predator Unmanned Air Vehicles (UAVs) that prowl the sky and the Unmanned Ground Vehicle (UGVs) such as Packbot and Talon that search for and render safe IEDs are operated by service members who are not located on the platforms. The service members have been removed from the system primarily due to the three Ds. The mission is too dirty, too dull, or too dangerous. This is the same reason we developed the Land Torpedo in World War I and Operation Aphrodite in World War II². The Land Torpedo was remote control vehicle laden with over 1,000 pounds of explosives that was intended to drive into the German trenches and explode. Operation Aphrodite was a similar effort where B-29 bombers were equipped with radio remote control instruments and television

¹ LTG Michael Vane, CDR ARCIC, interview held during Office Call, Fort Monroe VA, April 2010

² Peter W. Singer, Wired for War (New York: Penguin Press, 2009), p. 47.

cameras. The B-29s were then packed with 20,000 pounds of explosives. These planes would be launched with a crew from England. The crew would then set the aircraft for remote operation and bailout. A trailing aircraft would then fly the automated aircraft into a target that had been deemed too dangerous for a manned mission.

The current crop of UGV's lineage can be tied to work originally done under a Defense Advanced Research Project Agency program in 1998. The intent of this program was to develop highly maneuverable small ground robots that could be used in military and disaster relief operations³. iRobot and Foster Miller, the two companies involved in the program, eventually drove from Massachusetts to Ground Zero in New York City on September 11th, 2001 to aid in recovery operations. The demonstrated ability of these systems at Ground Zero resulted in these systems being deployed to Afghanistan for tunnel exploitation.

UGV Acquisition

The United States military has deployed well over 10,000 UGVs to Afghanistan and Iraq since the beginning of operations⁴. Where the Services normally acquire equipment through highly organized Programs of Record tied to detailed lifecycle management processes, this has not been the case with most of the robotic systems in theater. Approximately 80% of the deployed systems have been procured through the Joint Urgent Operational Needs process developed to address capability gaps that could result in combat loss of life or mission failure⁵. This acquisition shortcut is outside Acquisition 5000 processes to ensure that Combatant Commander's requirements are rapidly met. The Robotic Systems Joint Program Office (RSJPO), Joint Improvised Explosive Device Defeat Organization (JIEDDO), and the Rapid

³ Helen Greiner, interview held during the Fort Hood Robotics Rodeo, Fort Hood TX, September 2009.

⁴ MAJ Kevin Shrock, interview held during the Fort Hood Robotics Rodeo, Fort Hood TX, September 2009.

⁵ MAJ Seth Norberg, interview held during the Fort Hood Robotics Rodeo, Fort Hood TX, September 2009.

Equipment Fielding (REF) office are the principle avenues for these Commercial off the Shelf (COTS) acquisitions.

Though this ensures the battlefield commanders have the equipment they need to be successful, it does not provide for the type of integrated solutions that result from formal acquisitions. These robotic systems are often dropped into units as Theater Provided- Equipment once the units deploy or they are provided to units when they rotate through the Combat Training Centers (CTCs). Both of these solutions force the organization to develop ad hoc tactics, techniques, and procedures for their employment, transportation, unit training and sustainment. The litmus test for such non Modified Table of Equipment solutions should be – “If the equipment significantly changes how an organization completes its mission, the equipment must be available to the organization throughout its training cycle.” Otherwise, the new capability’s introduction renders the unit’s previous training as negative training.

Milestone C Acquisition Decision Memorandum

The December 2009 Acquisition Decision Memorandum (ADM) released by the Under Secretary of Defense for Acquisition, Technology and Logistics, Mr. Carter, covered the September 2009 Limited User Test approved Low Rate Initial Production for the Increment 1 systems.⁶ The memorandum, and the Limited User Test (LUT), questioned the value of these spinout capabilities. The ADM further directed a comparative analysis of units equipped with these systems and those without these systems as part of the September 2010 LUT. To support the 2010 LUT, the Director, Operational Test & Evaluation (DOT&E) has provided Measures of Merit to the Army for the comparative evaluation. Measures of Merit very similar to those

⁶ Ashland Carter, Increment 1 Early Infantry Brigade Combat Team Program Milestone C Acquisition Decision Memorandum, 24 Dec 09.

identified by DOT&E were used in a simulation experiment designed to measure the impact of UGVs on small unit's effectiveness.

A Comparative Analysis

A simulation experiment was developed to test the hypothesis that infantry units equipped with current Commercial Off the Shelf (COTS) robots are more effective than identical units without the equipment. The experiment would consist of multiple runs of company level offensive and defensive operations within a typical urban area of Baghdad against typically equipped Al Qaeda forces. The offensive operation consisted of a company level reconnaissance in force that develops into a hasty attack against squad-sized enemy within enemy controlled safe houses. The enemy will employ typical tactics to included IEDs, booby-trap, and defense in depth. The US forces will use current military tactics modeled from Army Field Manual 3-06.11 Combined Arms Operations in Urban Terrain and modified to accommodate the robot's capabilities. During the defensive operations, the company established platoon and squad-sized defensive positions within the same environment and were attacked by platoon and larger Al Qaeda elements. The experiment was modeled in One Semi-Automated Forces using entity behaviors developed by Program Executive Office – Simulation, Training and Instrumentation and robots controlled by their operator. No other Increment 1 systems were used in the simulation. The robot modeled in the experiment was the Small Unmanned Ground Vehicle, the current system being evaluated as part of Increment 1. The robot's basis of issue was one per squad.

Concept of Operations for the Employment of the Robotic System.

(Note: A concept of operations was developed specifically for the simulation based on FM 3-90. Though strikingly similar to those developed by the Army Experimental Task

Force (AETF) and Future Force Integration Directorate, the Commander of the AETF and Second Combat Arms Battalion (CAB) have indicated that subsequent training with the system has lead them to believe the tactical situation must dictate whether the unit first enters the building to be cleared with the robot and subsequently clears the building or if the unit enters the building and first secures a foothold and subsequently uses the robot to clear the rest of building.⁷⁾

A platoon ordered to clear a building in a small built up area can be expected to use its robots in a variety of ways capitalizing on the system's capabilities. During the approach to the building, the robot may be used to investigate suspected IED emplacements during the route reconnaissance. The lead squad could be expected to stop well short of the suspicious area while the robot moves into position to investigate. The robot will provide standoff while using electro-optical sensors and tactile feelers to try to detect tripwires or other initiation devices. Onboard manipulators would probe any suspicious areas and explosive chemical detectors could "sniff" the air in the area or sample any questionable substances. If hazards are found, the robot could disarm the firing device or detonate the IED using a sympathetic explosive charge.

As the platoon continues its movement, the robot could be used to provide observation of avenues of approach leading to the objective area. While in the observation post, the robot's enhanced day/night optics and audio sensors could be used to provide advanced warning to the unit.

Closer to the structure, the robot could be used to first investigate the building. It could approach as part of a lead element or on its own. Its speaker system could be used to establish first contact—broadcasting a greeting, warning, or instructions. Under ambiguous conditions,

⁷ COL Randy Lane, interview held with the Army Evaluation Task Force leadership, Fort Bliss, TX, March 2010

its cameras could be used to identify equipment or weapons held by civilians, identify known persons, or examine identity papers.

Under hostile conditions, the robot could be used to enter the building first. The robot could approach the building and enter through any ground-level opening or be thrown thru a window. Once inside it would relay video of the situation within the building including activities, location of personnel, and the layout of the structure helping the small unit leader identify the intent of the occupants. This understanding of situation within the building will provide the small unit leader with options he did not have before. This understanding gives him the opportunity to modify his clearing TTPs, choose to use indirect fire (mortar, M203, or other kinetic means based on the enemy disposition), or by-pass/otherwise engage if non-combatants are present – reducing collateral damage. Within the structure, the robot could also be used to investigate confined areas such as sewers and crawl spaces and help the small unit leader plan follow on operations with the structure and surrounding area. (A more detailed review of the CONOPS is presented in Appendix 1.)

Simulation Experiment Results

The study's results showed significantly increased effectiveness for infantry units equipped with robots when compared to identical organizations without the robotic capabilities based on measures of merit identical or parallel to those directed by DOT&E.

The robot-equipped organizations were more effective, more efficient, and more lethal. The most significant finding was based on the company's offensive capability. Integrated (manned/unmanned) units were twice as likely to be combat effective after the reconnaissance in force/hasty attack operation based on having 80% of personnel and equipment on hand after defeating the enemy. The increased post offensive operation combat effectiveness is most

probably due to the platform's mobility and ability to shoot second. Across offensive and defensive operations, the integrated unit was more lethal, killing 50% more enemy soldiers, and more survivable taking 57% fewer casualties. One result that was not expected was that operational tempo was decreased. Operations with robots took up to 40% longer to execute.

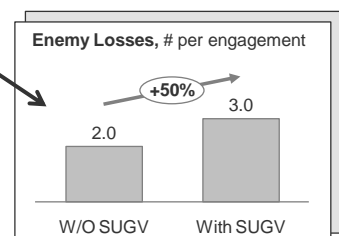
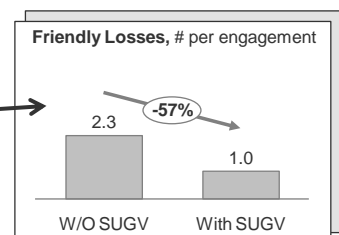
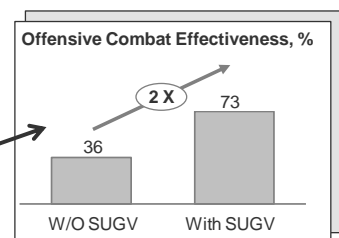
The integrated unit's ability to make contact with the smallest element (robot) and maintain contact with the enemy while preserving freedom of action is the organization's chief advantage. Coupled with the small unit leader's enhanced situational awareness, ability to minimize collateral damage and increased survivability the advantages are significant.

Simulation Study Results

Key Benefits

- **Increased Mission Success**
 - Increased post-operation combat effectiveness
 - Greater ability to engage NLOS
- **Improved Survivability**
 - Reduces friendly casualties by >50%
 - Significantly reduces IED casualties
- **Increased Lethality**
 - Increases enemy kill rate by 50%
- **Reduced Collateral Damage**

**Robots provide increased
SA & ability to engage
NLOS, increasing mission
success**



Source: Results from One Semi Automated Forces Simulator (1SAF) SIM model for SUGV tactical operations in both offensive and defensive scenarios

Doctrine, Organization, Training, Material, Leadership and Education, Personnel, Facilities and Policy (DOTMLPF-P)

The current and near-term integration of robotic forces should have limited impact on DOTMLPF-P and the Army is working many of these changes now. The integration and optimization of robot technology requires narrow changes to Doctrine, Organization, Training, Personnel, and Policy. The genesis of these changes is keyed to robotic systems being integrated into the force via a process similar to the Army's Training and Doctrine Command's Capabilities Development for Rapid Transition (CDRT) process. The CDRT process identifies battlefield capabilities that have been brought to theater via JUONS or other processes should become an enduring capability of the force as opposed to a temporary requirement that will be treated as disposable.⁸

Doctrine. The primary source for doctrine development for robotic infantry systems will be the efforts of the AETF and FFID. The Staffing Text 3-90 Future Combat Systems Spin Out Technology for the Infantry Brigade Combat Team, currently in development provides sufficient guidance for the integration and use of the robotic systems being used at Fort Bliss. The area that is not being exploited is the lessons being learned in theater with equally if not more advanced systems. There is no feedback loop between the work being done by FFID and deployed units.

Organization. UGV's current low level of autonomy has limited the operator:robot ratio to 1:1. A ground robot's operator must sacrifice his situational awareness to support the robot's operation. In situations where the operator cannot be secured by distance from enemy action, the unit must dedicate an additional soldier to provide the operator local security. This means that though UGV's offer irreplaceable capabilities to the force, they actually reduce the organizations

⁸ LTC Stuart Hatfield, interview held during the Ground Robotics Capabilities Conference, Miami FL, March 2010

ability to accomplish other tasks due to security requirements, the robot's impact on the soldier's load, and, therefore, the unit's agility. Organizational changes may be required to maintain the unit's overall effectiveness when equipped with various battlefield robots. Additionally, Joint Force Commanders have had to establish new organizations like the Joint Robotic Repair Facilities (TF Troy/TF Paladin) to support UGV operations in theater.

Training: The current impact on Training is a direct result of the REF procurement efforts to get the required capabilities to the operational force as quickly as possible. This has left the force without training manuals and an institutional base capable of training soldiers. As previously discussed, due to the fact that most of these systems are Theater Provided Equipment, organizations do not have the ability to train and become proficient with the systems as part of the normal Army Force Generation (ARFORGEN) train up process and are not able to train with the systems until they arrive a Combat Training Center or in theater. Additionally, the required training enablers such as simulations for these systems are not available on the installations.

Personnel . The use of these UGVs has also created unique skill sets within the force. Though the robots have been designed to require minimal operator training for their current capabilities, their maintenance requirements have imposed a significant maintainer-training requirement. Volunteer maintainers supporting the UGV fleet currently undergo 10-12 weeks of intensive training focused on the repair of multiple systems. They then spend a year maintaining/repairing systems that have been damaged in combat or through normal operation. These soldiers are currently then released back to their Military Occupational Specialty (MOS) or unit for re-assignment without the Army or Marine Corps capturing the fact that these soldiers have gained significant expertise that will likely be needed in the future. The Department needs

to begin tracking these trained robotic maintenance personnel with an Additional Specialty Indicator (ASI).

Policy: The department and services have to review and develop policies associated with the application of force by armed robots. The current “man in the loop” model used with UAVs will support the eventual weaponization that will occur with the development of the Armed Robotic Vehicle-Light that is still under development, but is expected to be part of Increment 2. The main question on policy is how to apply self-protection or anti-handling capability to small ground robots. The ground battlespace is much more complex than the air domain and one of the critical complications ground robots will face is the direct contact with the enemy and the enemy’s use of “innocents” as surrogates to impede the operational use of the ground robots. The simplest anti-handling device is to cover the robot with observation and fire. This technique ceases to be effective once the robot is employed out of the operator’s line of sight. Under these circumstances, the robot becomes vulnerable to enemy action or the use of children to blind, over-turn, or otherwise impairs the robot. As the robot is not under observation, the anti-handling capability must be enemy initiated. Additionally, the Army must determine what degree of force is appropriate in these applications, audible warnings, dazzlers, riot agents, electrical shock or other solutions.

As the Army has recognized the imperative to field these small ground robots and has begun the programmatic requirements of programs of record there are two significant factors that impact the acquisition strategy – relative low cost and ground robot’s capabilities relationship to Moore’s Law.

Ground Robots as a System of Systems

The Army has regarded ground robots as a collection of sub-systems since the inception of the Future Combat System program. In developing the requirements and awarding contracts for the Small Unmanned Ground Vehicle, different contractors were selected to provide the mobility platform and the electro-optical robot head.⁹ This model has continued through the development of the Army's Training and Doctrine Command's (TRADOC) Initial Capability Document (ICD). The ICD envisions modular components for mobility, sensing, communication, manipulation/mission specific tools, and autonomy.¹⁰ Sensing and autonomy modules are critical to the role, capabilities, and operator burden associated with robotic systems and are highly correlated to Moore's Law.

Autonomy and sensing are interconnected because the ability of the robot to function without operator intervention is tied to the robot's ability to understand its environment. The National Institute of Standards and Technology (NIST) has developed a model relating autonomy to the complexity of the environment, the complexity of the require task, and the amount of human interaction¹¹. The Autonomy Levels for Unmanned Systems (ALFUS) model has been selected as the reference model for the Army's Joint Ground Robotics Integration Team¹². The model uses standards in Task/Mission Complexity, Environmental Complexity, and Human Interaction to try to measure the overall autonomy of the system. The intent is to be able to adequately compare very dissimilar systems – a refrigerator and a unmanned ground vehicle – that both sense their environment and act with/without human intervention to

⁹ Alan Weeks, Program Manager Small Unmanned Ground Vehicle, interview iRobot Headquarters, Bedford MA, September 2009.

¹⁰ TRADOC Robotic Initial Capability Document Brief, TRADOC Lethality Branch, 11 December 2009.

¹¹ National Institute of Standards and Technology Ad Hoc ALFUS Working Group, Autonomy Levels for Unmanned Systems Framework, NIST Special Publication 1011-II-1.0, December 2007.

¹² Joint Ground Robotics Integration Team, Fort Benning GA, October 2009.

accomplish some task/mission. On the face of it, a refrigerator is perfectly autonomous – it senses its internal temp and acts to maintain or reduce the temperature as required. It requires no human intervention, it will even defrost itself. The UGV may be able to orient itself in certain configurations, establish self-healing networks, or follow a moving object-small autonomous steps to support larger tasks/missions that are largely tele-operated. The inclusion of task/mission complexity and environmental complexity allows a more objective comparison of sophisticated systems. The area of the plain graphed when measuring these factors measures the autonomy of the system. The resulting evaluation is a Contextual Autonomous Capability (CAC) - High, Mid or Low.

High (7-10): Completes all assigned missions with highest complexity; understands, adapts to, and maximizes benefit/value/efficiency while minimizing costs/risks on the broadest scope environmental and operational changes; capable of total independence from operator intervention.

Mid (4-6): Plans and executes tasks to complete an operator specified mission; limited understanding and response to environmental and operational changes and information; limited ability to reduce costs/risks while increase benefit/value/efficiency; relies on about 50 % operator input

Low (0-3): Remote control for simple tasks in simple environment.

Sensing and autonomy are critical to the development of the acquisition strategy for these systems, because the robots will become much more capable due to improvements in these systems absent any improvement to the robots mechanical and communications systems. Technology refresh and pre-programmed software upgrades will provide the force with state of the art capabilities at reduced costs.

This discussion does not mean that these systems will enter depot level repair and recapitalization programs. The December 2009 Combined Arms Support Command Sustainment Center of Excellence Maintenance Strategy for Robots study recommended maintenance strategy did not include advanced repair and upgrade.¹³ These systems' vulnerability to battlefield damage, projected technological obsolescence, and projected full rate production costs approaching \$100,000 may not dictate full spectrum maintenance strategies.

Acquisition Options - A Cost-Benefit Analysis

In accordance with the 30 December 2009 Under Secretary of the Army/Vice Chief of Staff memo on enterprise decision making, a cost-benefit analysis (CBA) must be conducted prior submission of unfunded or new program requirements can be considered.¹⁴ As the Robotics ICD and associated CBA provide the clear value proposition that the benefits of the development and fielding of unmanned ground systems, the Army must consider the appropriate fielding strategy to meet the warfighter's requirements with constrained resources. The three proposed courses of action are: Status Quo - Continue to provide small unmanned ground systems to deploying units as Theater Provided Equipment (TPE Option), Identify unmanned ground systems as Modified Table of Organization and Equipment (MTOE) requirements and fielded in accordance with basis of issue plans for each type of equipment (MTOE Option), and the Establishment of installation based pools of unmanned ground systems that are available for training in addition to Theater Provided Equipment and Combat Training Center pools (Installation Supplemental Pool Option). All of these options would require modifications to

¹³ Combined Arms Support Command Sustainment Center of Excellence Maintenance Strategy for Robots, December 2009, pg 6-6.

¹⁴ Under Secretary of the Army and Vice Chief of Staff of the Army memorandum on Cost-Benefit Analysis to Support Army Enterprise Decision Making, 30 December 2009

Doctrine, Organizations, Training, Material, Leadership and Education, Personnel, and Facilities. The courses of action (COA) will be evaluated against cost, readiness, and fleet management.

COA 1 - TPE Option: Continue to provide small unmanned ground systems to deploying units as Theater Provided Equipment. This option would continue the current practice of having unmanned ground systems available to units within theater and at the Combat Training Centers (CTCs). Units would train with the unmanned systems during their equipment draw at the CTCs and modify their tactics, techniques and procedures during the capstone rotation. Organizations would fall in on the equipment during their in-theater relief in place/right seat-left seat rides and adopt the tactics techniques and procedures they had developed during their CTC rotation. The sustainment infrastructure would remain the same as currently used with pooled maintenance assets controlled at the theater level.

CAO 2 - MTOE Option: Identify unmanned ground systems as Modified Table of Organization and Equipment (MTOE) requirements and field in accordance with basis of issue plans for each type of equipment. This course of action will field brigade level sets as part of Brigade Combat Team (BCT) capability packages to the 29 infantry BCTs as part of the Army Force Generation Model (ARFORGEN). The basis of issue is expected to consist of 50 robots per infantry brigade combat team as well as associated logistics and support materials. As MTOE equipment, the units would have continuous access to the equipment for operational training, maintenance, and planning.

COA 3 - Installation Supplemental Pools: Establishment of installation based pools of unmanned ground systems that are available for training in addition to Theater Provided Equipment and Combat Training Center pools. Installations with appropriate assigned organizations would manage and maintain unit sets of equipment from which organizations

could draw equipment for training. The unmanned ground vehicles would be maintained and upgraded by the installations. Organizations would continue to draw unmanned systems for use at the CTCs and would “fall-in” on the theater provided equipment once deployed.

Comparison of Alternatives

Comparison of the COAs across the evaluation criteria will be done via relative rankings. Due to the current undetermined costs of the systems, working status of the existing Tactics, Techniques and Procedures being developed within TRADOC, and a formalization of a projected maintenance and upgrade strategy, certain assumptions have to be made.

Assumptions:

1. Basis of issue will be 2 per infantry platoon and 50 per brigade.
2. Maintenance for MTOE equipment will be provided organically by the brigade combat team.
3. Industry will be able to provide substantive upgrades in terms of sensors and autonomous behaviors for the platforms every two years.
4. The unmanned ground systems mobility, manipulation, and communication systems can be reliably maintain for a minimum of 6 years (2 ARFORGEN Cycles)
5. The costs associated with doctrine changes across the force will be equal for all COAs.

Cost:

Compare total costs across DOTMPF. 3 will be awarded to the lowest cost and 1 to the highest cost alternative.

COA 1 is the lowest cost option and is awarded a 3 in relative rank. Due to the fact that the equipment is only available for training in theater and at the CTCs there are no changes required for Organization, Training, Material, Logistics, Personnel, or Facilities.

COA 2 is the highest cost option and is awarded a 1 in relative rank. Establishing unmanned ground systems as MTOE equipment will require significant changes to organizations to include changing maintenance structures, inclusion of operators at the unit level, and provision for transportation assets to move the systems. Training costs with this COA will also be the highest based on operator and maintainer training, as well as organizational training with the systems. Material costs will be the highest because this COA acquires the most brigade sets. Facility costs will also increase to accommodate the larger operational and logistics footprint.

COA 3 is the second most expensive option and is awarded a 2 in relative rank. Cost is reduced from COA 2 due primarily to the number of brigade sets of equipment that will need to be purchased. The number of brigade sets should be at least halved based on the distribution of IBCTs across the Army. This will have corresponding effect on the changes to the operational and support costs.

Readiness:

Compare the impact on organizational readiness across the force. 3 will be awarded to the highest readiness and 1 to the lowest readiness alternative.

COA 1 is the option that provides the lowest readiness and is awarded a 1 in relative rank. Due to the fact that the equipment is only available for training in theater and at the CTCs organizations can be expected to be less proficient in its use and less mission capable. There will, however, be a slight increase in maintenance and support readiness as these functions are concentrated in theater level organizations with concentrated expertise. In areas such as

Afghanistan, however, there has been a corresponding delay in repairs, due to the transportation constraints in theater.

COA 2 will provide the highest level of readiness and is awarded a 3 in relative rank. As MTOE equipment, units will have the opportunity to train routinely on individual and collective tasks associated with the unmanned systems. Additionally, the familiarization will support the development of advanced TTPs and leadership appreciation of the system's capabilities. Supporting maintenance and logistics organizations will have the opportunity to maintain the systems and keep them operational during all phases of the ARFORGEN Cycle. This will keep the support in tune with the operational needs and enable repair further forward and more quickly during operations.

COA 3 provides the second highest level of readiness and is awarded a 2. With multiple users competing for the same resources, units will not have the same familiarity and proficiency with the equipment as they will under COA 2. Smart scheduling of the systems, like any finite resource such as training areas and ranges, can meet all unit requirements, but pooled resources reduces access, opportunity training, TTP refinement, and proficiency.

Fleet Management:

Fleet Management is measured as the ease with which the enterprise can manage unmanned system resources across the force and make the most capable systems available to the deployed forces. 3 will be awarded to the simplest management structure and 1 to the most complex.

COA 1 is neither the most or least complex management structure and is awarded a 2 in relative rank. The fact that the fleet only has two segments – in theater and at the CTCs - lends simplicity to the management structure. The complexity of this structure comes with the

norming of the fleet with the regularly scheduled substantive sensor and autonomy upgrades. Under COA 1 unmanned systems in theater will have to be upgraded while units are in contact. The management of the upgrade and the time the systems are not available to the operational units is critical. Additionally, though enhanced autonomy will make the systems easier to use, operators will have to go through re-training and organizations will have to build confidence with the new capabilities.

COA 2 is least complex management structure and is awarded a 3 in relative rank. Establishing unmanned ground systems as MTOE equipment will mean that units will progress through the ARFORGEN cycle with a stable platform and capability. This will support proficiency and confidence in the equipment and capabilities. Additionally, if critical upgrades are required outside the ARFORGEN reset, the unit commander can manage that change because the equipment is organic.

COA 3 is most complex management structure and is awarded a 1 in relative rank. COA 3 has all the complexity of COA 1 with the addition of an additional segment of the fleet. Under high operational tempo (OPTEMPO) conditions with multiple user units on an installation drawing from the pool you will likely have units at different stages of the ARFORGEN cycle. The management challenge becomes the sequencing of installation assets, CTC assets, and TPE as appropriate to each brigade combat team's garrison location and position in ARFORGEN.

Recommendation:

The comparison of courses of action yields the recommendation to pursue COA 2, the inclusion of unmanned ground systems as MTOE equipment with the 29 IBCTs of the operating force.

	Cost	Readiness	Fleet Management	Total
COA 1 – TPE Option	3	1	2	6
COA 2 – MTOE Option	1	3	3	7
COA 3 – Installation Supplemental Pools	2	2	1	5

Tabulated Comparison of Alternatives – High score wins

Risks of Proceeding

There are two main risks of proceeding. The first risk is that the Army Brigade Combat Team Modernization Program will fail to spinout an appropriate material robotic solution for the force. Though many of the Spinout 1 capabilities have been troubled and subsequently terminated or sent to the technology base, the Small Unmanned Ground Vehicle has been the most successful technology so far and has been proven effective without the associated enabling technologies. The other risk is that the Army will begin the fielding of the unmanned systems and the nation will disengage from Iraq and Afghanistan. Such disengagement will reduce the urgency of acquiring the unmanned systems and potentially cause force contraction due to budget pressure.

Risks of Not Proceeding

The two main risks of not proceeding are risk to the force and failure to meet congressional directives to prioritize unmanned systems. The force will continue to confront tactical situations where ground robots can significantly improve their effectiveness and survivability. Failure to eliminate this tactical risk will increase the risk at the operational level. The second risk is statutory. Congress has directed the Department of Defense to adopt unmanned solutions to material problems through the Warner Amendment and 2007 Defense Authorization Act.

Conclusion

The infantry forces currently fighting in urban areas of Iraq and Afghanistan could become significantly more effective and efficient through the integration of current commercially available unmanned ground systems as MTOE equipment. Even without the other Increment 1 technologies such as the network and Unattended Ground Sensors, the Unmanned Ground Vehicle can dramatically improve the operational performance of these formations. To support this integration, the Army needs to make narrow changes to existing DOTMLPF-P requirements and move these systems in to the MTOE of these units. The flexibility of these platforms means they can be upgraded to be compatible with the networked Increment 1 technologies once the network is operational and can be maintained as “State of the Art” through software and hardware upgrades.

APPENDIX - SMALL UNMANNED GROUND VEHICLE (SUGV) CONCEPT OF OPERATIONS

Purpose: To provide information regarding the employment and use of the SUGV as part of the operating forces. This appendix describes the basic employment concepts to understand how this system can be employed.

Using the SUGV will save service member lives. Ensuring the SUGV will be used effectively will require operators be trained on all aspects of employment of the SUGV and will require leaders to be trained on employment techniques and ways in which the SUGV will increase the reconnaissance and surveillance capabilities of the small unit.

Description: The SUGV is a “man packable” robotic system, weighing less than 35 lbs, consisting of a robotic operator control interface, a robotic chassis platform with video capability, digital communications/audio relay modules (plug in/out), advanced sensors/mission modules, and both a soft case and “ruggedized” storage container. Organic to Infantry, Engineer, Chemical, MP, and Reconnaissance units, these small systems can be efficiently packed for storage on organic vehicles in the unit and then transported or man-packed in the Modular Lightweight Load-carrying Equipment (MOLLE) system for dismounted operations. The SUGV is capable of being re-configured for other missions by adding or removing mission payloads.

U.S. Forces will use the SUGV to conduct extended reconnaissance and surveillance of urban and complex terrain and subterranean areas to gain and sustain information domination and assess land domination (above and below ground) by the force commander. The SUGV provides vital information regarding buildings, field fortifications, tunnels, sewers, subways, bunkers, facilities, and other structures in support of military operations, peacekeeping, and other Stability and Support operations (SASO).

The Small Unmanned Ground Vehicle (SUGV) will support the following tasks:

- Remotely provide reconnaissance capability in urban terrain and subterranean battle space
- Remotely detect, interrogate and neutralize as required potential improvised explosive devices, booby-traps, landmines, and explosive threats to friendly forces in buildings, bunkers, tunnels, sewers, and other urban features
- Remotely locate or by-pass threat obstacles in buildings, bunkers, tunnels, sewers, and other urban features
- Remotely detect subterranean avenues of approach to assist in the preparation of obstacle plans
- Remotely assess bomb damage and subterranean structural integrity of facilities and buildings
- Disaster relief operations in support of civil authority

Each Infantry Rifle squad in the IBCT, HBCT and SBCT, Reconnaissance squad in H/S/IBCT, and MP, Chemical and Engineer units, including separate units will have the SUGV. The SUGV serves as an unmanned sensor platform for the Infantry, Engineer, Chemical, MP, and Reconnaissance Team/Squad/Platoon leader to gather information without directly exposing service members to hostile action. Tactical formations will not have SUGV operators but will delegate operation to any member selected by the leader for each mission. Therefore, training must be provided to selected members of each organization.

Pre-employment: Prior to combat operations, leaders will conduct pre-combat inspections on the SUGV as with all other pieces of equipment. Inspections will focus on serviceability, maintenance, and battery status. Leaders will select the SUGV payloads that match the current mission profile. Appropriate payloads will be placed on the SUGV. Additional payloads will be packed with the HQ's elements additional equipment.

Employment: During employment the SUGV is transported with its assigned unit. The SUGV will be carried by a Soldier/operator to a release/employment point. At this point the SUGV will travel on its own under the control of a designated operator.

Where the small unit employs the SUGV will be mission dependent but most likely will be in an area where it is covered and concealed from enemy or threat view. The Soldier/Sailor/Marine with the SUGV controller controls the movement, speed and provides directions to the platform using data provided by the driving sensors on the platform. The service member controlling the SUGV will remain concealed from the threat to ensure the enemy does not detect him or fire in his immediate direction. The SUGV's overall mission will be directed by the small unit leader who will provide the operator updated directions or guidance.

Employment Concept for Urban Operations

For urban operations the SUGV is ideal for many missions where the small unit can remain in over watch while the SUGV conducts reconnaissance/surveillance missions. Units can send it down a street, a hallway or put it down sewer systems to look for threats and reduce the risks to Soldiers by the stand-off provided by the SUGV. The SUGV is well suited for going first into buildings, caves and other areas where service members are often easily ambushed or attacked. Based on pre-deployment training exercises in urban and complex terrain conditions units will develop Tactics, Techniques and Procedures (TTPs) for employment of the SUGV.

Such training and proficiency will ultimately determine time factors to complete certain types of tasks like “clear 1000 ft of a sewer system” or clear an entire floor of “so many square feet.”

Units training with the SUGV will develop TTPs that work for their unit and their anticipated missions and will gain an understanding of the times required and the skills needed during operation of the platform to identify threats to the small unit.

The following is a vignette to illustrate an Infantry unit’s employment the SUGV during an assault in an urban area. In this instance, the Infantry platoon’s mission is to move tactically to seize an objective. This will include seizing and clearing building’s enroute to the objective. The unit first isolates a specific building by establishing Support by Fire (SBF) positions with their organic weapons and/or vehicles.

The Assault Team, consisting of two squads, sends one SUGV to deploy a smoke grenade to provide obscuration for their tactical movement to the building. They use the second SUGV to locate an acceptable breach point into the building. The breaching team, consisting of the third squad, breaches the building. When entering the building through the breach point the breaching squad will deploy their SUGV into the building first via doorway, window, or other entry. The SUGV’s small size will allow it to be thrown over walls or through windows. Using the SUGV to make initial entry will reduce the service member’s exposure to enemy fire and reduce the danger to non-combatants within the structure. Once within the structure, the SUGV operator can maneuver the robot throughout the building, including multiple floors, to determine the threat, as well as asses the best course for clearing the structure. During clearing operations the SUGV can be used to see around corners, in hallways and stairwells before troops enter any dangerous areas. The SUGV can also be used as a sensor to provide rear security or as an observation post to observe for enemy reinforcements.

Once the building is secure, the squads consolidate and reorganize, establish security, and prepare to continue the mission. SUGV may be deployed forward of the squads to provide early warning and continued observation of the area. The platoon leader may use the SUGV to monitor specific avenues of approach such as enemy mouse-holes between adjacent buildings, covered routes to the building, and underground routes into the building.

Employment Concept for Subterranean Operations

Before entering a subterranean passage with Soldiers, a squad will conduct reconnaissance inside with a SUGV. Similar to its use in a building; the SUGV will lead in front of the Soldiers allowing them to see the enemy before the enemy can see them.

Before entering the cave, the lead squad sends its SUGV inside. Based on line of sight and the composition of the surrounding materials a fiber optic spooler may be required. The SUGV moves through the cave until it encounters an intersection. The operator will then stop the SUGV and look as far as he can see in each direction using both low-light cameras and active illumination. Using the information provided by the SUGV, the platoon leader will gain a better understanding of the situation. The Platoon Leader will send his lead squad into the cave to the location of the SUGV at the intersection. Upon arrival the squad will secure the intersection and continue leap-frogging into the tunnel.

The lead squad will now send their SUGV down the tunnel to the right until they encounter another area of interest. In this instance the SUGV encounters a room off the right side of the tunnel. The operator sends the SUGV into the room. The operator was able to see that the room was filled with ammunition. This information is sent to the Platoon leader by the operator's Squad Leader. With this information the platoon leader sends the 2nd squad forward to secure and mark the newly found chamber.

The lead squad leader recalls his SUGV and continues the mission into the next tunnel off the intersection. The SUGV moves down the tunnel until the operator identifies a three-way intersection with tunnels ahead, behind and to the left. Here the squad leader directs the operator to stop the SUGV and carefully look down each of the tunnels. Down one of the tunnels, the SUGV operator sees enemy soldiers positioned behind a pile of rubble. The Platoon Leader is advised of this information and quickly devise a course of action to destroy the enemy position at minimum risk to his Soldiers. This process continues throughout the cave clearing operation and enables the leaders to consistently see and understand first by leading with the SUGV. This minimizes risk to friendly forces and enables rapid mission success.

Employment Concept for Chemical Weapon Detection

An Infantry Platoon has been given the mission to clear a cave suspected of containing chemical weapons. The Platoon Leader gives the mission of clearing the cave to first squad. Second squad will follow first squad and provide security for first squad during the operation. Third squad and the weapons squad will secure the area around the cave. The Platoon Leader places his entire element into MOPP II.

The first squad leader directs his SUGV operator to prepare the SUGV with the Chemical Hazard Detection and Identification payload module. The operator removes the SUGV from its MOLLE and places the SUGV into operation in less than 5 minutes including conducting pre-operations checks on the SUGV. The operator then removes the Chemical Hazard Detection and Identification payload module from its MOLLE and places the Chemical Hazard Detection and Identification payload module onto the SUGV. The first squad moves to a position where they can observe the entrance to the cave with second squad moving to a position to the right of first

squad to provide local security. The squad leader directs the SUGV operator to activate the Chemical Hazard Detection and Identification payload module and to drive the SUGV into the cave entrance. The operator drives the SUGV with the driving sensor into the cave entrance. The squad leader and operator observe the view from the SUGV into the cave entrance displayed on the SUGV controller via the driving sensor on the SUGV. The SUGV is then moved farther into the cave to investigate the entire cave. The operator sees a stack of munitions inside the cave and moves the SUGV closer to the munitions to allow the Chemical Hazard Detection and Identification payload module to monitor the air in the vicinity of the munitions. The SUGV operator stops the SUGV beside the stack of munitions. The controller gives an alert that a chemical agent has been detected by the Chemical Hazard Detection and Identification payload module by emitting an audio warning and providing a visual warning via an NBC 1 report on the controller within 5 seconds of detecting the presence of chemical contaminants. The Chemical Hazard Detection and Identification payload provides the SL and operator with the date/time of detection, the identification of the type of chemical agent detected, the dosage detected and the level of concentration at the sensor. The squad leader informs the platoon leader of the information provided by the sensor.

The platoon leader calls his company and requests assistance in clearing the cave. An element from a chemical unit is sent to the caves location to conduct the actual decontamination of the area. While waiting on the arrival of the chemical unit, the SUGV continues to monitor the area inside of the cave. When the chemical unit arrives the platoon assumes the security mission for the chemical unit. The Platoon goes to MOPP IV. The SUGV is driven from the cave by the operator and is moved away from the rest of the platoon. The operator then decontaminates the SUGV and the Chemical Hazard Detection and Identification payload. Once

the decontamination of the equipment is completed, the operator places the Chemical Hazard Detection and Identification payload back into its MOLLE and prepares the SUGV for the mission of aiding the platoon in providing security for the chemical unit clearing the cave.